COMPOSITE BUILDING MATERIAL AND PANELS MADE THEREFROM

REFERENCE TO RELATED APPLICATION

The present application claims the benefit of U.S. Provisional Application No. 60/267,122 filed February 8, 2001, the disclosure of which is hereby incorporated by reference in its entirety into the present application.

BACKGROUND OF THE INVENTION

Field of Invention:

The present invention relates generally to composite materials and the building structural components made therefrom. More particularly, the present invention relates to composite structural panels made primarily of recycled synthetic and naturally-occurring materials and that are used to construct basic shelter, low-cost houses and other structures such as schools, churches, clinics, and external storage sheds.

Description of the Prior Art:

The world's population is estimated at over six billion people. Within the next 20 to 25 years, that population is projected to exceed 10 billion. Population-induced problems exist world-wide, but are predominantly shared by those living in economically-distressed countries with large populations. One such population-induced problem includes substandard or a lack of basic housing and other building structures, such as clinics and storage facilities. The lack of basic housing and other structures in these countries has been addressed by using low-cost, pre-fabricated building components that are both durable and strong, in addition to being easy to assemble by local laborers having little training or experience in the construction trade.

U.S. Patent No. 5,327,699, for example, discloses a flat, square-shaped panel module for use in assembling building structures. The panels are fabricated in one location and then delivered to a construction site for assembly into floors, walls, roofs and roof trusses to produce various sized building structures. Their flat, square shape reduces shipping costs and facilitates shipping overseas, making them attractive for use in

areas where traditional U.S. construction materials and techniques may not be readily available. Some of the panels may include conduits or channels for electrical and plumbing works. Each panel includes an inner and outer surface filled with foam insulation. The patent discloses panels made from, among other things, recycled products such as ceramic, glass, plastic and aluminum. One disadvantage of the disclosed flat panel modules is that most of the strength of the modules is provided by one or more load-bearing members running through the center of the panels or along the edges of the panels. The foam insulation interior layer provides little weight-bearing support.

Some modular systems are designed to be partly assembled at the construction site. U.S. Patent No. 5,974,751, for example, discloses a hollow, thermoplastic, interlocking structural component that may be filled with concrete at the construction site to form building elements such as walls. The structural components may be made of reprocessed (or recycled) plastic and conduits may be included in the structural components by inserting pipes before pouring the cement. Although using light-weight plastic forms like those disclosed in this patent can reduce shipping costs and are relatively simple to assemble by untrained laborers, a source of concrete must be provided at the site and skilled labor must be available to produce the finished structural members. Thus, in certain parts of the world, these forms may not be used to address basic shelter, low-cost housing needs.

As noted above, specialty structural modules can be fabricated having integrated utility conduits for electrical wires, plumping and ventilation, which reduces on-site labor and construction costs. U.S. Patent No. 6,308,465, for example, discloses a rectangular, pre-cast module containing existing utility systems and coupling elements for fastening to other utility modules. The panels may include portions made of various polymeric substances, including polyurethane, polyisocyanate and polyurethane-polyisocyanurate structural foams. A suitable mixing device or mold is used to produce the plastic components. The fabricated modules are then shipped to a construction site and placed on a foundation as part of the construction of a building.

To reduce the cost of modular building panels, recycled materials are often used in addition to other additives. U.S. Patent No. 6,044,604, for example, discloses a

composite roofing board having a paper layer made of recycled paper fibers. Glass strands or glass fibers are also disclosed as possible components of the panels. U.S. Patent No. 5,718,096 discloses using recycled materials and glass fibers in composite panel elements for use in building structures. U.S. Patent No. 6,322,731 discloses the use of rice husks, wheat husks and sawdust in forming constructions panels.

Many of the above-identified patents disclose panels made of layers of various materials: a bottom and top layer and one or more inner layers sandwiched between the outer layers. One advantage of using layered composite panels for building structures like houses is that the layers can, depending on the layer material used, provide dimensional stability, heat transfer resistance and an aesthetic appearance. U.S. Patent No. 5,483,778, for example, discloses a layered, modular construction panel having dimensional stability and aesthetic surface features. One disadvantage of layered panels is that the manufacturing method can be costly and complicated compared to other manufacturing methods, like extrusion, pultrusion, and compression of polymeric materials.

As noted above, the advantages and disadvantages of pre-fabricated, modular construction panels are numerous. U.S. Patent No. 6,322,731 states that the use of composite panels can achieve a desired strength-to-weight characteristic and provide thermal and acoustic insulation properties satisfying basic housing needs. However, a major problem with known fabrication techniques is that there is a practical limit to the maximum length of the individual panels that can be used for floors, walls and roofs. That in turn leads to the requirement for smaller panels to be joined end to end to form a combined panel assembly of the necessary size. Typically, however, it has been identified that inadequate techniques for joining the panels have resulted in such structures being relatively weak. The resultant loss of structural integrity has, in turn, resulted in the potential strength characteristics not having been realized in larger scale applications, particularly for use in housing. For that reason, composite panels have tended only to be used to form internal partitions and non-load bearing walls, where significant structural integrity is not required. Accordingly, as noted in U.S. Patent No. 6,322,731, a separate framing structure is still required and the inherent problems associated with conventional building methods have remained largely unsolved.

SUMMARY AND OBJECTS OF THE INVENTION

In view of the foregoing, it should be apparent that there exists a need for a low-cost composite building material that can be formed into building structural panels using a relatively simple and inexpensive manufacturing process, such that the panels have adequate dimensional stability, durability and flexibility features making them ideal for constructing low-cost, basic housing structures in locations around the world.

Accordingly, it is a principal object of the present invention to provide a composite material that is composed primarily of recycled polymer composite material, including polyolefins such as polyethylene and polypropylene.

It is another object of the present invention to provide a composite material that is composed of recycled polymer composite material and various additives to increase the strength, flexibility, durability, and permanence of the composite material.

It is still another object of the present invention to provide a composite material that includes various amounts of other natural or synthetic recycled or virgin substances in proportions that will contribute to the structural integrity or other features of the material.

It is another object of the present invention to provide a structural panel made of a low-cost, easy to manufacture, composite material such that the structural panel is modular but retains an adequate level of versatility.

It is still another object of the present invention to provide a structural panel made of a composite material using various plastic forming manufacturing technologies, including, but not limited to, compression, injection-compression and extrusion.

It is another object of the present invention to provide a structural panel of sufficient thickness and rigidity to constitute vertical weight-bearing walls or horizontal ceiling or floor structures.

It is still another object of the present invention to provide a structural panel having common structural features for simplifying the assembly process.

It is another object of the present invention to provide a structural panel that can be attached to other structural panels to form a building, such that the assembling of panels requires minimal training, education, tools and other resources.

It is still another object of the present invention to provide a structural panel that can be rapidly attached to other structural panels to permit the fabrication of a single structural unit in approximately one day by a team of three to five people.

Briefly described, these and other objects and features of the present invention are accomplished, as embodied and fully described herein, by a composite material that is formed into basic structural panels that can be subsequently assembled into the floors, walls, roof trusses, and roofs of buildings by unskilled labor having access to basic tools. Thus, basic shelter, low-cost houses and various other structures, such as schools, churches, clinics, and storage facilities, may be constructed. The building material for the panels is a molded polymer composite, made from either homogeneous or non-homogeneous materials. The material consists primarily of recycled polyolefins, primarily polyethylene and polypropylene compounds with or without various additives being added, including glass fiber, metals and naturally-occurring materials such as rice husks, sugar cane bagasse, nut shells, talc, clay, sand and wood. Other polymeric compounds and additives may also be used.

The structural panels made from the composite material are fabricated using various plastic forming techniques, including, but not limited to, compression, injection-compression, extrusion, and pultrusion, in a mold. Those processes are capable of providing durable structural panels of sufficient strength and density for many different applications, like those noted above. The basic structural panel is common to all single-unit and multiple-unit structure configurations, which can be produced from variants of the same mold, thus reducing manufacturing costs. However, minor differences in the structural panels provide increased versatility. For example, some of the panels may be modified to include conduits for electrical wiring, plumbing and ventilation and a cross-ribbed reinforcement grid may be included for strength. As formed, the basic structural panel may be made into wall panels, mitered wall panels, floor panels, roof/ceiling panels, and roof truss panels.

Each structural panel may be provided with flanges at their edges in which there are holes that align with holes on other structural panels for fastening the structural panels together using various fasteners. Sealants or adhesives may be applied to the interfaces between the structural panels. Vertical or horizontal rods may also be placed to run through the available channels formed in the composite material to enhance structural stability.

The method of the present invention is carried out by providing pre-fabricated structural panels for assembly into a low-cost, simple to assemble building structures; providing a simple schematic capable of being understood by people of different languages having, in some instances, little literacy skills; fastening the various structural panels together to form a floor, walls, and a roof; and fastening the floor, walls and roof together to form a basic, low-cost shelter.

With these and other objects, advantages and features of the invention that may become hereinafter apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the invention, the appended claims and to the several drawings attached herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing of a perspective, exploded view of a basic structural unit capable of assembly from the components of the invention;

FIG. 2a is a drawing of a bottom view of a structural panel used for the floor shown in **FIG. 1**;

FIG. 2b is a drawing of a side view of the structural panel shown in **FIG. 2a**;

FIG. 2c is a drawing of a top view of the structural panel shown in **FIG. 2a**;

FIG. 3a is a drawing of an interior view of a structural panel used for the walls shown in **FIG. 1**;

FIG. 3b is a drawing of a side view of the structural panel shown in **FIG. 3a**;

FIG. 3c is a drawing of an exterior view of the structural panel shown in **FIG. 3a**;

FIG. 4a is a drawing of a right side view of a left-center portion of a roof truss shown in **FIG. 1**;

FIG. 4b is a drawing of a side view of the left-center portion of the roof truss shown in **FIG. 4a**;

FIG. 4c is a drawing of a left side view of the left-center portion of the roof truss shown in **FIG. 4a**;

FIG. 5a is a drawing of an interior view of an upper roof structural panel used for the roof shown in **FIG. 1**;

FIG. 5b is a drawing of a side view of the upper roof structural panel shown in **FIG. 5a**;

FIG. 5c is a drawing of an exterior view of the upper roof structural panel shown in **FIG. 5a**; and

FIG. 5d is a drawing of an interior view of a bottom roof structural panel used for the roof shown in **FIG. 1.**

FIG. 5e is a drawing of a side view of the bottom roof structural panel shown in **FIG. 5d**;

FIG. 5f is a drawing of an exterior view of the bottom roof structural panel shown in **FIG. 5d**;

FIG. 6 is a drawing of a partial perspective view showing one method of fastening two panels of the present invention together.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Several preferred embodiments of the invention are described for illustrative purposes, it being understood that the invention may be embodied in other forms not specifically shown in the drawings.

FIG. 1 is a drawing of a perspective, exploded view of a basic structural unit **100** capable of assembly from the components of the present invention. As shown in **FIG. 1**, the basic structural unit **100** includes a floor **102**, four walls **104a–104d**, four roof trusses **106a–106d** and a roof **108**. Various openings may be provided in the walls **104a–104d** for one or more windows **110** and a door **112**. A soffit **111** is formed by the overhanging portion of the roof **108** to cover a porch (not shown).

As also shown in **FIG. 1**, the floor **102**, the walls **104a–104d**, the roof trusses **106a–106d** and the roof **108** are made from individual structural panels fastened together. It will be appreciated by one of ordinary skill in the art that various configurations and sizes of the structural unit **100** may be assembled without deviating from the spirit and scope of the invention. For example, structural units that are two or three times larger than the basic structural unit **100**, in terms of square footage, may be assembled by fastening additional individual structural panels to the basic structural unit **100**. A fewer or a greater number of roof trusses **106a–106d** may be used than the four shown in **FIG. 1**. The roof may be flat instead of pitched. A fewer or a greater number of openings in the walls **104a–104d** for doors and windows may be used than the number shown in **FIG. 1**. One wall, for example the wall **104c**, may be eliminated if an open shelter is to be assembled. Additional walls like the wall **104a** may be added to the interior of the structure to provide for separate rooms and to support the roof **108**. In sum, the modularity of the building structural panels disclosed herein can accommodate many different building configurations.

FIG. 2a is drawing of a bottom view (i.e., exterior side) of a single floor structural panel **200** used to make the floor **102** shown in **FIG. 1**. Each floor structural panel **200** having a unitary molded structure of recycled polymer composite material of standard unit dimensions. A plurality of individual floor structural panels **200** are fastened together to form the floor **102** using any one of a variety of fastening techniques. For example, fastening devices, including, but not limited to, bolts, plates, pins, wedges, and clamps may be used. These fastening devices may be made of plastic, metal, wood or other materials. Compatible adhesives or glues applied to the abutting surfaces of the individual floor structural panels **200** may also be used.

To enhance dimensional stability, a raised, cross-ribbed, reinforced grid **202** is incorporated into the floor structural panel **200**. Around the outer edge of the floor structural panel **200** is a perimeter flange **204** for fastening the floor structural panel **200** to the walls **104a–104d** and to each other. The flange **204** may include a plurality of holes or slots (**FIG. 6**) for accepting the fastening devices. The floor structural panel **200** is of sufficient thickness *h*, as shown in **FIG. 2b**, and rigidity to support vertical load

forces. **FIG. 2c** is a drawing of a top view (i.e., interior side) of the floor structural panel **200** showing a smooth surface for walking.

The floor structural panel **200** (and all of the other panels disclosed herein) is preferably made of a polymer material. The polymer material consists primarily of recycled or virgin polyolefins, including, but not limited to, polyethylene and polypropylene compounds. Other compounds may be added, including, but not limited to, glass fiber, metals and naturally-occurring materials such as rice husks, talc, clay, sand, and wood. Those additives may be used to increase the performance parameters of the floor structural panel **200**, including the strength, flexibility, durability and permanence of the panel. The weight of the material as formed should be about 6.4 kilograms per square meter (kg/m^2), but that can range dramatically higher or lower depending on the density and amount of the polymers and additives that are used.

As shown in **FIGS. 2a–2c**, the preferred shape of the floor structural panel **200** (and many of the other panels disclosed herein) is square (i.e., having a unit dimension 1×1, 2×2, etc.). However, it is contemplated that other shapes may be used, including panels that are rectangular, triangular, rounded on one or more sides, or are tetrahedral shaped (i.e., the four corners forming other than 90-degree angles). It has been determined that a particularly advantageous unit dimension for the square panels of the invention is about 1.25 m on edge. It has also been determined that a rectangular panel having dimensions of about 1.25 m by about 2.5 m on edge is also advantageous. The approximate weight of those panels is about 10 kg or 25 kg, respectively, but this can range dramatically higher or lower depending on the density and amount of the materials that are used to make the panels.

FIG. 3a is a drawing of an interior view of a wall structural panel **300** used for the walls **104a–104d** shown in **FIG. 1**. The wall structural panel **300** is essentially identical to the floor structural panel **200** except that the raised perimeter flange **304** (as best seen in **FIG. 3b**) along the outer edge of the wall structural panel **300** extends above the smooth outer surface **306** (**FIG. 3b** and **3c**). The perimeter flange **304** is used for fastening the wall structural panel **300** to the floor and to each other. The flange **304** (**FIG 3a** and **3b**) may include a plurality of holes or slots (**FIG. 6**) for lining up with holes or slots on other flanges and thereby receiving fastening devices to join the wall

structural panel **300** to other panels. Compatible adhesives or glues applied to the abutting surfaces of the individual wall structural panels **300** may also be used. A raised, cross-ribbed, reinforced grid **302** incorporated into the wall structural panel **300** is also provided.

It is also contemplated that one edge of the wall structural panel **300** may be replaced with a mitered edge **312** (shown as a phantom line in **FIGS. 3a** and **3b**). The wall structural panel **300** is of sufficient thickness *h*, as shown in **FIG. 3b**, and rigidity to support both horizontal and vertical load forces.

The wall structural panel **300** may include pipes, channels, wires or raceways to provide for electricity, plumbing, heating, ventilation and air conditioning if a more complete structure is desired. The opening **308**, for example, could be used to accommodate a water supply line passing from the exterior to the interior of the wall structural panel **300** (see **FIG. 3b**). The conduit **310** could be used to accommodate electrical wires running from one edge of the wall structural panel **300** to the other edge (**FIG. 3b**). The conduit **310** could also be integrated into the material of the wall structural panel **300**. Of course, the other structural panels of the invention could also include those additional utility features.

To increase the stability of the wall structural panel **300**, one or more vertical or horizontal rods **314** may also be placed to run through the available channels formed in the composite material, as best seen in **FIG. 3c** (only one rod shown for illustration purposes). The rods may be made of metal, plastic or fabric.

Joining the wall structural panel **300** and the floor structural panel **200** is accomplished through a variety of possible fastening devices, including, but not limited to, bolts, plates, pins, wedges, and clamps. Those fastening devices may be made of plastic, metal, wood or other materials.

Various openings may be provided in the walls **104a–104d** for one or more windows **110** and doors **112** (**FIG. 1**). Such openings are preferably formed during the molding (or other) process of fabricating the structural panels. Alternatively, the openings may be added by physically removing (i.e., by cutting) some of the material from the wall structural panel **300** after it has been fabricated.

FIG. 4a is a drawing of a right side view of a roof truss structural panel **400** according to the present invention. The roof structural panel **400** forms the left-center portion of the roof trusses **106a–106d** (as best seen in **FIG. 1**). A similarly shaped roof truss structural panel (essentially a mirror of the roof structural panel **400**) is fastened to the roof structural panel **400** (see **FIG. 1**). The smaller left edge of the roof structural panel **400** is fastened to another roof truss structural panel to form a complete roof truss **106** to support the weight of the roof **108** (**FIG. 1**).

As shown in **FIG. 4a**, the roof truss structural panel **400** includes a raised, cross-ribbed, reinforced grid **402** (see also **FIG. 4b**). Around the outer edge of the roof truss structural panel **400** is a raised perimeter flange **404** for fastening the roof truss structural panel **400** to the wall structural panels **300**, the roof structural panels **500** (**FIG. 5**) and to each other. The flange **404** may include a plurality of holes or slots (**FIG. 6**).

FIG. 4c is a drawing of a left side view of the roof truss structural panel **400** showing the smooth surface **406**. It is preferred, but not necessary, that the roof truss structural panels **400** at the exterior position of the structure have their smooth surface **406** facing the exterior of the structure. It will be appreciated that a basic structural unit **100** (**FIG. 1**) may be designed and assembled with or without the utilization of the trusses **106a–106d** depending upon the load support that the roof **108** requires and the design and specification of the structure. Also, the roof truss structural panel **400** may be designed differently, such as, it may be hollow at the center and there may be a different raised, cross-ribbed reinforced grid **402** in some locations (or no grid at all).

FIG. 5a is a drawing of an interior view of an upper roof structural panel **500** used for the roof **108** shown in **FIG. 1**. The upper roof structural panel **500** includes a raised, cross-ribbed, reinforced grid **502** (see also **FIG. 5b**). The exterior surface **506** of the upper roof structural panel **500** is smooth as shown in **FIG. 5c**. Along three edges of the upper roof structural panel **500** is a raised perimeter flange **504**. The raised perimeter flange **504** may include a plurality of holes or slots (**FIG. 6**). Upon fastening those sides of the upper roof structural panel **500** to other panels, a flashing (not shown) may be affixed to the seam to prevent leakage.

As shown in **FIG. 5a**, it is preferred that a row of slots or holes **508** for ventilation be provided along the edge of the upper roof structural panel **500** that forms the apex of

the roof **108** (**FIG. 1**). It will be appreciated by one of skill in the art that the ventilation slots/holes **508** may be omitted from the basic structural unit **100** where they are not needed. Of course, the size, shape, location and number of ventilation slots/holes **508** can vary widely.

FIG. 5d is a drawing of the interior view of a lower roof structural panel **510** used for the roof **108** shown in **FIG. 1**. The lower roof structural panel **510** includes a raised, cross-ribbed, reinforced grid **512** (also shown in **FIGS. 5e** and **5f**). The exterior surface **513** of the lower roof structural panel **510** is smooth as shown in **FIGS. 5e** and **5f**. Along two sides of the lower roof structural panel **510** is a raised perimeter flange **514** as shown in **FIG. 5f**. The raised perimeter flange **514** may include a plurality of holes or slots as best seen in **FIG. 6**. Upon fastening the flanges of the lower roof structural panel **510** to similar panels or to the upper roof structural panel **500**, a flashing (not shown) may be affixed to the seam.

To assemble the roof **108**, several upper roof structural panels **500** and lower roof structural panels **510** can be fastened together, as noted above (i.e., with a combination of fasteners, adhesive, or flashing). Different shaped panels may be required along the lower portion of the roof **108** where the roof overhangs the front of the basic structural unit **100** to form the soffit **111** as best seen in **FIG. 1**. (The front of the basic structural unit **100** in this case refers to the side corresponding to the wall **104a**). The soffit **111** of the roof **108** can be used to cover a porch area (not shown). The lower roof area corresponding to the soffit **111** would preferably not have a raised perimeter flange **504** on the horizontal edges of the panels so that rain water and debris can flow freely off of the roof **108**. It may be necessary to extend the width of the roof truss structural panel **400** to support the weight of the extended portion of the roof **108**.

FIG. 6 is a drawing of a partial perspective view showing how two panels of the present invention may be fastened together. In this case, two wall structural panels **300** are positioned side-by-side with the flanges **304** of the respective wall structural panels **300** facing each other. The holes **602** on the flanges **304** are lined up to accept a fastening device **604** (in this case, a bolt and nut). The flanges **304** may not include holes **602**, in which case other fastening devices **604** could be used, such as a clamp or screw. Or, a combination of fastening devices **604** may be used. For example, a clamp or screw

could be used in addition to the bolt shown in **FIG. 6**. Also, there may be a greater or fewer number of holes **602** than the number shown in **FIG. 6**.

The method of fabricating the panels of the present invention includes using various plastic forming technologies. For example, a mixture of homogeneous or non-homogeneous polyolefins is introduced into a batch or continuous mixer along with desired amounts of additives such as glass fiber, or naturally occurring additives such as rice husks, sugar cane bagasse, nut shells, talc, clay, sand and wood. The materials are combined at an appropriate temperature and duration to produce a thoroughly mixed product that can be introduced into a mold having the shape of a structural panel of the present invention. Part of the mold may be blocked to form the frame of a door, window or other openings as described above.

The basic structural unit **100** will consist of approximately 25 or 50 structural panels, depending on the overall size of the individual panels. The panels are assembled three panels in width (**FIG. 1**) to form a structure that is about 2.5 m high and 3.75 m on each side. The area of such a structure is approximately 14 m^2 (150 ft^2).

Although certain presently preferred embodiments of the disclosed invention have been specifically described herein, it will be apparent to those skilled in the art to which the invention pertains that variations and modifications of the various embodiments shown and described herein may be made without departing from the spirit and scope of the invention. Accordingly, it is intended that the invention be limited only to the extent required by the appended claims and the applicable rules of law.